IMAGE BASED ANALYTIC SURFACE REPRESENTATION AND MESH GENERATION

E. Bekkers[a] and **C. Taylor**[b]

[a]Department of Mechanical Engineering
Stanford, CA 94305-4038
ebekkers@stanford.edu

[b]Departments of Mechanical Engineering,
Surgery and Pediatrics
Stanford, CA 94305-4038
taylorca@stanford.edu

Image based modeling is the process of converting imaging data into a computational model. Our work has been motivated by the need to convert large (three- dimensional) medical imaging volume data sets into finite element models. An important step in this process is the representation of the boundary (or surface) of the domain of interest. Biological structures can have complex topological shape and span an enormous range of size and curvature scales; as a result, the surface representation methods we have developed need to be robust and topologically independent, making them useful for a wide range of surface representation problems. Currently, our method generates a cubic NURBS tensor product surface that is C2 continuous except at a number of "extraordinary" (3 or 5 faces/ vertex) vertices, where it is G1. Our work improves previous surface reconstruction techniques [1] through the development of a novel automatic base mesh generator, the utilization of lower order B- spline patches, and the incorporation of subdivision surface techniques [2]. The modeling procedure begins by filtering the volume data; this can include smoothing, edge enhancement, or level set analysis. The resulting volume data is assumed to have a unique isosurface that corresponds to the surface of interest. We work directly with a planar triangulation of this isosurface obtained with the Marching Cubes algorithm. This representation, though extremely accurate, is very dense and lacks multiresolution ability, thus making it less useful as input to a (volume) mesh generator. Our goals are to 1) perform a decimation to generate a base mesh and then 2) use this base mesh as the control mesh for a subdivision surface that will be least squares fit to the underlying dense mesh. Decimation proceeds by randomly placing vertices and then "growing" patches of various radii (depending possibly on curvature, topological or other values) using a triangulated version of the Fast Marching Method [3]. This is repeated until the surface is covered with patches, and the resulting structure is the Voronoi diagram for the chosen vertices. The dual structure to this Voronoi diagram is a Delaunay triangulation of the surface. Triangles are combined pairwise to form squares. The resulting triangle/ square surface then undergoes one Catmull- Clark subdivision, to form the entirely quadrilateral "base mesh". The vertices of this base mesh are then taken as control points for a NURBS representation to the limit Catmull Clark surface [2]. Since the control points uniquely determine the surface, they can be considered independent variables in a surface optimization routine: data points are efficiently projected onto the surface, and the control points are moved in a manner so as to minimize the least square distance between all data points and the surface. Applications to a variety of surfaces will be demonstrated.

Acknowledgments: This work was supported through an NIH Biocomputation Training Grant #GM63495 and NSF ACI-0205741

References

[1] Matthias Eck, Hugues Hoppe, "Automatic Reconstruction of B-spline Surfaces of Arbitrary Topological Type", ACM SIGGRAPH, 1996, pg.325-334.
[2] Jorg Peters, "Patching Catmull- Clark Meshes", ACM SIGGRAPH 2000, pg. 255-258.
[3] Kimmel R.,Sethian J., "Fast Marching Methods on Triangulated Domains", Proc. Nat. Acad. Sci., 95, pg. 8341-8345.